RESEARCH DEPARTMENT

AN OUTLINE OF SYNCHRONOUS STANDARDS CONVERSION USING A DELAY-LINE INTERPOLATOR

Report No. T-096

(1962/31)

THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

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July 1962

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SUMMARY

This report outlines the principles of a television standards converter suitable for use where the field periods of the input and output signals are equal and coincident. Some methods proposed in the past are reviewed briefly and an elementary description is given of a further method that is potentially capable of good results without making excessive demands upon the performance of circuit elements.

1. INTRODUCTION

So far, standards conversion has been mainly used either for international programme exchanges or for "slaving"* signals from a remote source. The majority of present-day converters are based upon the well-known cathode-ray-tube/camera-tube combination. Provided that the cathode-ray-tube phosphor and camera-tube storage characteristics are suitably chosen, such a combination may store picture information for a time sufficient to permit satisfactory conversion between standards differing in both line and field periods.

In some future applications, however, the field periods of the input and output signals may be equal and coincident, and the conversion may involve a change only in the number of lines per field. For these applications, signal processing may be devised which avoids assembling the input signal in pictorial form (e.g., as a visible image at the screen of a cathode-ray tube). Signal processing equipment of this type may be termed a "synchronous" standards converter.

2. GENERAL

2.1. Basic Processes of Synchronous Conversion

Two basic processes must be carried out by a synchronous converter. These are:

(i) the selective rejection or repetition of input information (e.g., the changing of the number of lines per field to suit the required standard)

and

(ii) the redistribution of the selected information in the new time scale (e.g., the lengthening or shortening of the duration of each selected line).

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*In the "slaving" application, the nominal television standards are unchanged. The converter is used to derive, from non-synchronous input signals, an output that is synchronous with local signals.

The instrumentation of these two processes requires a storage device capable of storing at least one input line. With the storage device, means must be provided for "writing in" information at input line frequency, "reading out" the stored information at output line frequency and erasing the stored information when necessary. If the conversion involves a decrease in the number of lines per field, erasure may be carried out by the reading process; if the number of lines per field is to be increased, then erasure of the stored information should occur as new information is fed in.

Fig. 1 illustrates the behaviour of a synchronous converter of this type, in terms of the input signal corresponding to an inclined row of picture points (A, B, C, etc.) and a reduction in the number of lines per field by a factor of 4/3. The first basic process is carried out by simply rejecting every fourth line of each input field together with all the information it contains. For convenience input point A, on input line 1, is shown reproduced at the coincident point "a" on output line 1. However, since the vertical positions of the selected lines are altered by the second basic process, the input point B is reproduced at "b" and the point C is reproduced at "c". As every fourth input line is rejected, input point D is eliminated. The points E, F, G and H, lying on the next four input lines (Nos. 5, 6, 7 and 8) are treated similarly. From Fig. 1 it will be appreciated that the reproduced output picture will show geometric distortion in the form of discontinuities; a corresponding form of distortion results for the case where the number of lines per field is increased.

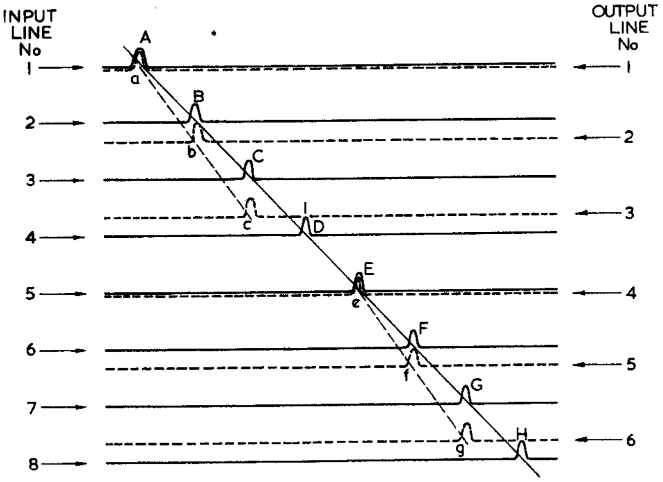
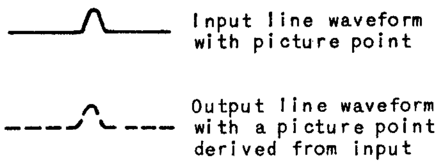


Fig. 1 - Synchronous conversion without interpolation: The portrayal of an inclined row of picture points


Input line waveform with picture point
Output line waveform with a picture point derived from input

2.2. Simple Interpolation

If a simple form of interpolation is incorporated, the output picture contains information derived from all the input lines and a better result is obtained. Fig. 2 shows the effect of adding interpolation to the conversion illustrated in Fig. 1. Thus any output line that does not coincide in position with an input line includes information, suitably weighted in amplitude, from two adjacent input lines. As before, point A on input line 1 is reproduced at the coincident point "a" on output line 1. However, output line 2 lies between input lines 2 and 3 and reproduces points B and C at "b_1" and "c_1" respectively; the amplitudes of "b_1" and "c_1" may be related to the distances $B\ b_1$ and $C\ c_1$. Similarly, output line 3 includes contributions "c_2" and "d_1" from C (input line 3) and D (input line 4). The effect of this form of interpolation is to reduce subjectively the geometric distortion at the cost of some slight loss of the horizontal sharpness of a sloping edge.

3. PREVIOUS PROPOSALS

Practical proposals have been made for synchronous standards converters embodying the basic processes outlined here. One early proposal[1] did not incorporate interpolation between input lines, and employed lumped-constant delay networks whose delay could be switched from the duration of one input line to the duration of one output line. As originally described, this proposal was limited to applications where the numbers of lines per field at the input and output are related by simple factors.

A storage device suitable for use as a synchronous standards converter has been proposed as the "redistributing" store in a bandwidth-compression system.[2] This form of store, as applied to synchronous conversion, is illustrated in Fig. 3. It consists, basically, of two electronic "rotary" switches having equal numbers of contacts (one for each picture element in one line, say 500). Corresponding contacts on each switch are connected together and to a storage condenser. The input switch arm A moves steadily from contact I_1 to contact I_n during one input television line and the output arm B moves from O_1 to O_n during one output line. During one input line, provided that the input source impedance is low, every condenser (C_1 to C_n) will assume a charge proportional to the signal amplitude of a picture element. During one

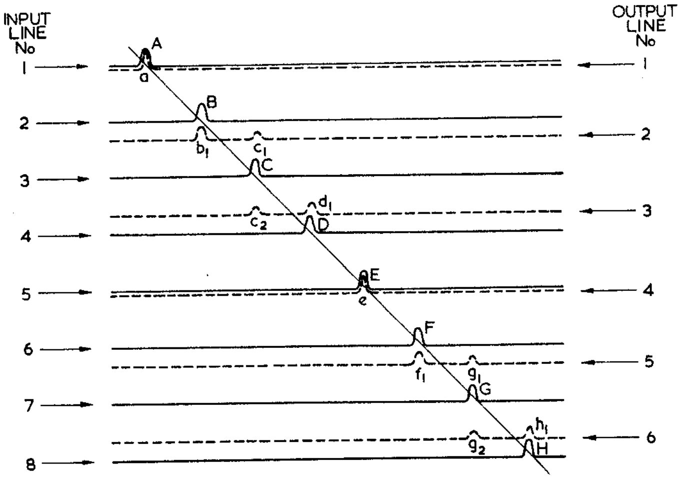
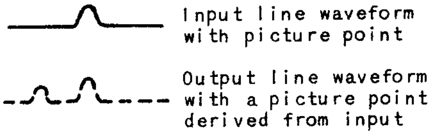


Fig. 2 - Synchronous conversion with simple interpolation: the portrayal of an inclined row of picture points


Input line waveform with picture point
Output line waveform with a picture point derived from input

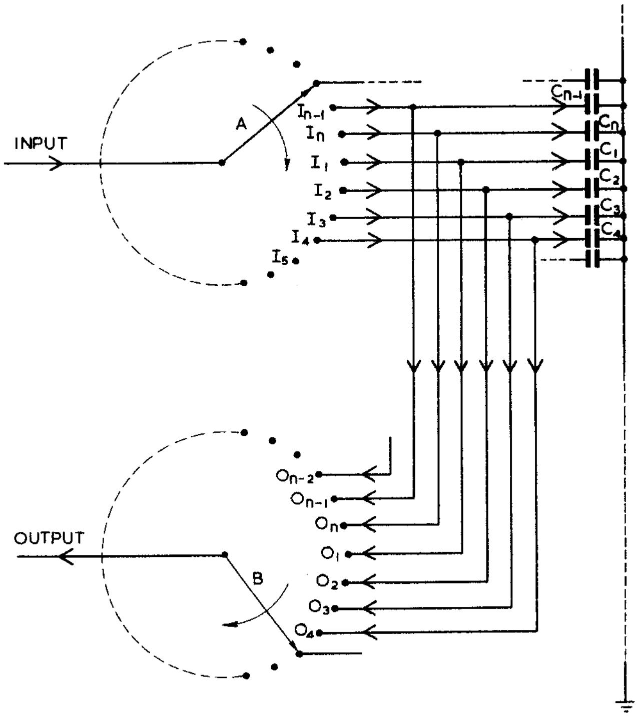


Fig. 3 - A "Redistributing" store employing electronic rotary switches

output line, each condenser is connected, in turn, to the output terminal. For a conversion involving a reduction in the number of lines per field the arm A revolves faster than B. In these circumstances a condenser may be connected to the input twice between samplings by the output switch which, in turn, may be permitted to discharge the condenser into the load impedance. On the other hand, a conversion involving an increase in the number of lines per field implies that B revolves faster than A. In this case the output switch may sample a condenser twice between chargings by the input switch; under these circumstances the impedance presented to the condenser, by the output, must be very high.

As far as the authors are aware, the use of a redistributing store in synchronous standards conversion was first revealed in a recent patent proposal.[3] This arrangement incorporates two switches similar to those shown in Fig. 3 but instead of a direct connection (together with a storage condenser), each pair of corresponding contacts are connected through a low-pass filter having a cut-off frequency of the order of half the input line frequency; the filters act as both storage and interpolating elements.

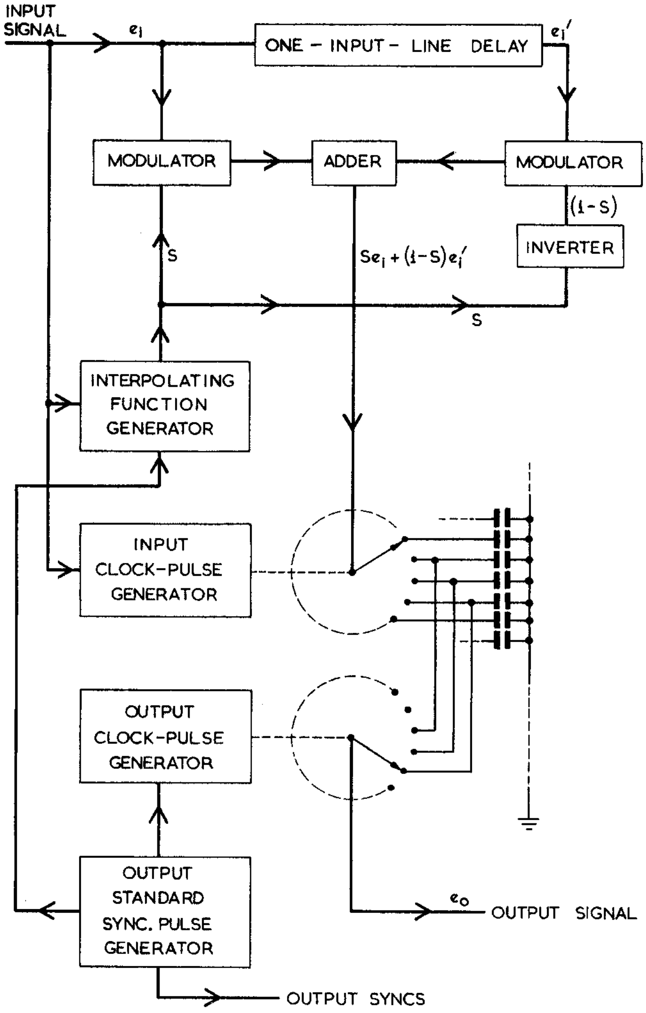


Fig. 4 - A synchronous standards converter using a delay-line interpolator

4. THE PROPOSED METHOD

A method[4] has been devised which is based directly upon the arguments outlined in Section 2. In this case a redistributing store, such as that shown in Fig. 3, is preceded by an interpolator employing a delay line. Fig. 4 outlines a typical form suitable for a conversion involving a reduction in the number of lines per field by a factor less than two.

It will be seen that the one-input-line delay permits both the input signal e_1 and the corresponding signal e_1' (from the previous input line) to be available simultaneously. The two signals are then modulated by the time functions S and $(1 - S)$ respectively and the modulator outputs are added together. These operations upon the input signal are equivalent to the process of interpolation illustrated in Fig. 2. The complete period of the waveform S is equal to that of the beat between the input and output line frequencies.

The sum of the outputs from the modulators, $Se_1 + (1 - S)\ e_1'$, is fed to the redistributing store from which the converted output is obtained; the "rotary arms" of the electronic switches are moved from contact to contact by clock generators producing pulses at n times the input and output line frequencies, where n is the number of contacts on each switch.

The shape of the interpolating time function S is determined by the form of interpolation chosen and, in a typical arrangement, will be of sawtooth form with a flyback occupying one input line. The interpolation law may be expressed in terms of an equivalent aperture. Some interpolating apertures, and their corresponding spectra, are illustrated in Fig. 5. The ideal form (a) is perhaps somewhat impractical in that a large number of one-line delays would be required. Form (b), zero-order interpolation, represents an aperture producing the situation illustrated in Fig. 1 and, hence, is of little interest. Apertures of the types shown in (c) and (d) are of practical interest in that they imply the use of a single one-line delay and have spectra that indicate a tolerable loss of vertical detail. The modulating waveforms S corresponding to these latter apertures consist of a linear sawtooth and a "half-cosine"* sawtooth respectively.

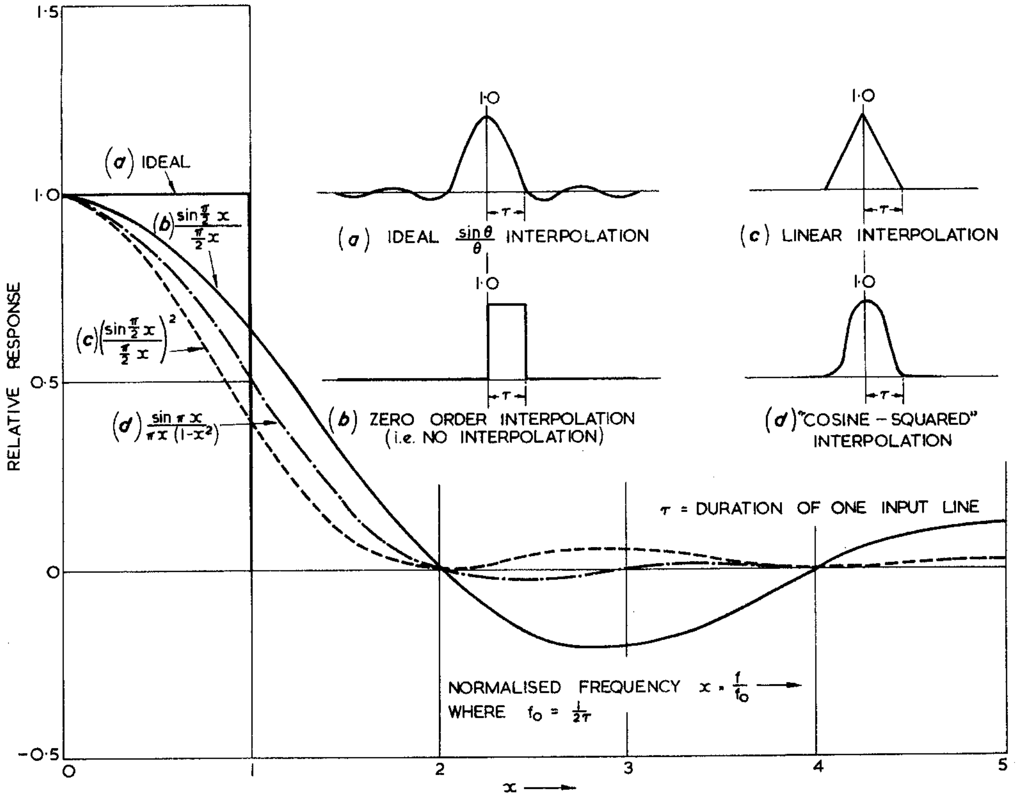


Fig. 5 - Some interpolation apertures and their spectra

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*The "half-cosine" sawtooth consists of a wave whose active portion may be expressed by

$$S(t) = \tfrac{1}{2}\ (1 - \cos\theta) \qquad 0 < \phi < \pi$$

and whose period is equal to one beat cycle. For the converter described here, the flyback shape is arbitrary.

In a practical form, a converter of the type described could employ established circuit techniques. A suitable one-line delay has been developed[5] and devices suitable for use in electronic rotary switches have been reported.[6]

This form of converter offers several potential advantages when compared with those previously proposed. For example, each of the processes of interpolation and redistribution, being separate, may be performed at the optimum contrast law. Further, the signal to be redistributed may be converted to digital form,[7] stored suitably and be re-converted to the analogue form at the output. Finally, it is possible that the converter may be able to take advantage of some proposals for contour interpolation.[8,9]

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